



Engineering, Operations & Technology
Boeing Research & Technology

Research & Technology

Defense System Perspectives on Multifunctional Design for Actuation

*presented to The 2nd Multifunctional
Materials for Defense Workshop
July 30 – August 3, 2012*

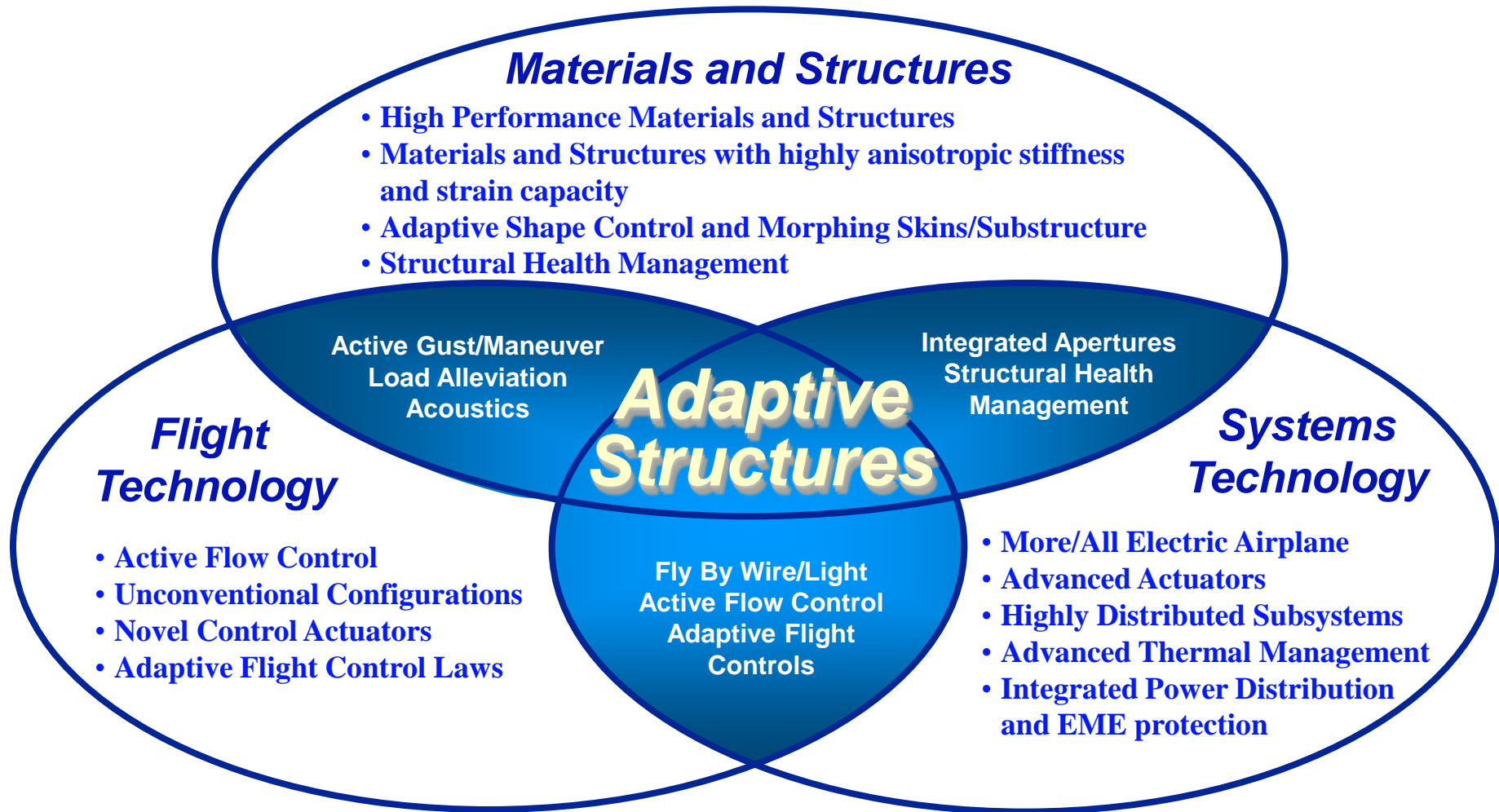
Edward V. White
Adaptive Structures Technology Focus Team Lead
Boeing Research and Technology
314-232-1479
edward.v.white@boeing.com

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE AUG 2012		2. REPORT TYPE		3. DATES COVERED 00-00-2012 to 00-00-2012	
4. TITLE AND SUBTITLE Defense System Perspectives on Multifunctional Design for Actuation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Boeing Research and Technology, St. Louis, MO, 63166				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Presented at the 2nd Multifunctional Materials for Defense Workshop in conjunction with the 2012 Annual Grantees?/Contractors' Meeting for AFOSR Program on Mechanics of Multifunctional Materials & Microsystems Held 30 July ? 3 August 2012 in Arlington, VA. Sponsored by AFRL, AFOSR, ARO, NRL, ONR, and ARL. U.S. Government or Federal Rights License					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 9	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Adaptive Structures Need for Multifunctional Systems Design

Engineering, Operations & Technology | Boeing Research & Technology

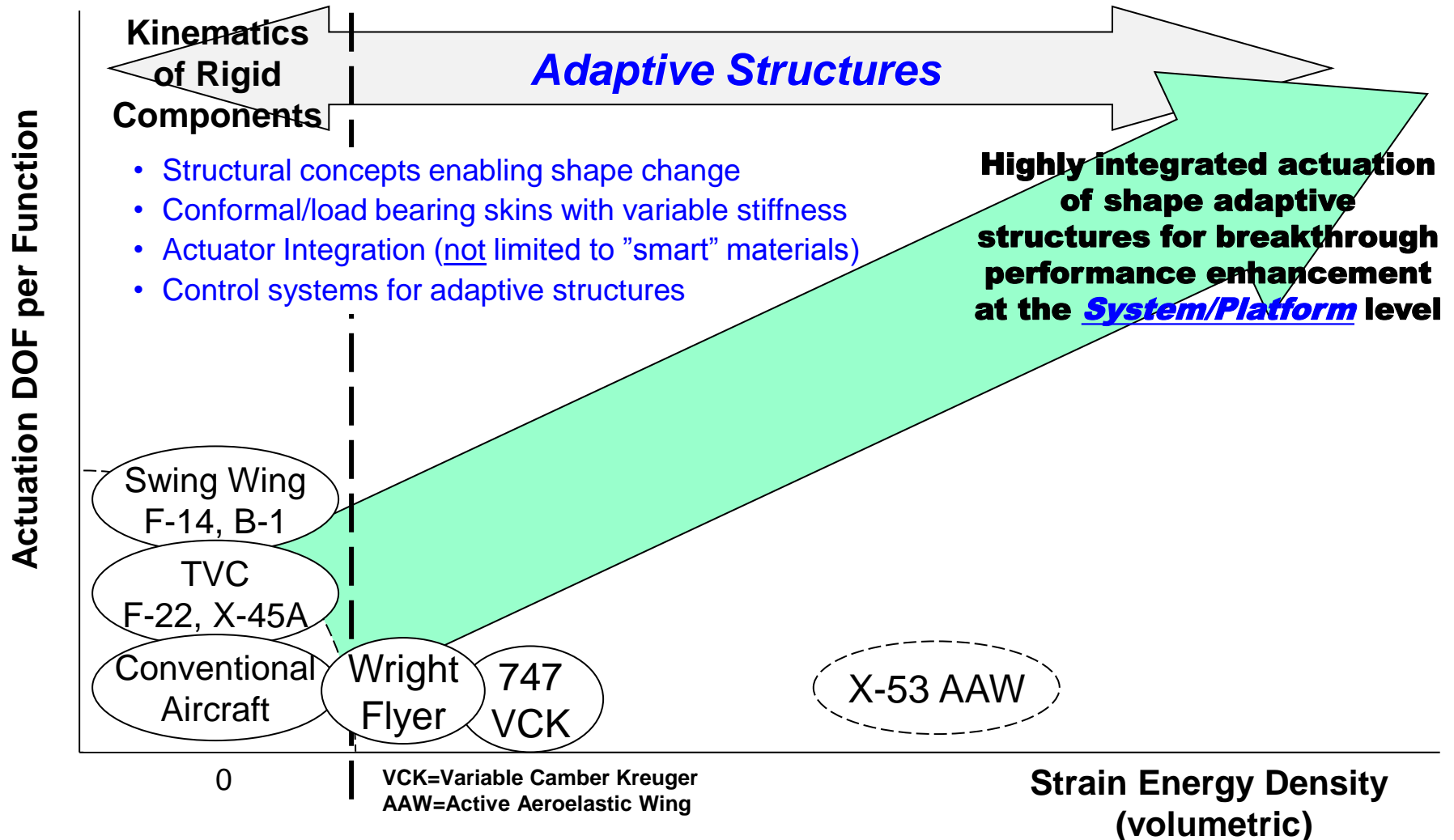
Multifunctional Structures



Adaptive Structures Design Space

Engineering, Operations & Technology | Boeing Research & Technology

Multifunctional Structures



DARPA SAMPSON Program - Aircraft Inlet Shape Control

Engineering, Operations & Technology | Boeing Research & Technology

Multifunctional Structures

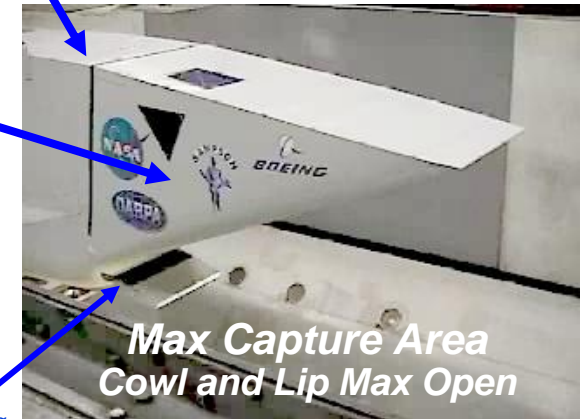
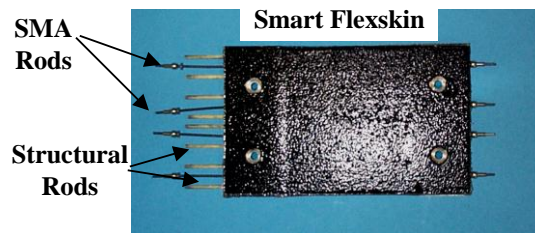
Major Program Accomplishments

- ❑ *First full-scale demo of smart materials to provide large forces and displacements*
- ❑ *First integration of SMA rod actuators within compliant skin structure*

SAMPSON = Smart Aircraft and Marine Projects System Demonstration
SMA = Shape Memory Alloy

- ❑ Met: Integrated SMA actuator system into F-15 Inlet cowl
- ❑ 6000 Lbs Force Demonstrated
- ❑ Capable up to 20,000 Lbs
- ❑ 6 inches Displacement
- ❑ Flow speeds up to Mach = 0.8

- ❑ Met: Integrated SMA actuators into smart flexskin to drive leading edge flap
- ❑ LE deflection > 20 degrees
- ❑ Flow speeds up to Mach = 0.8

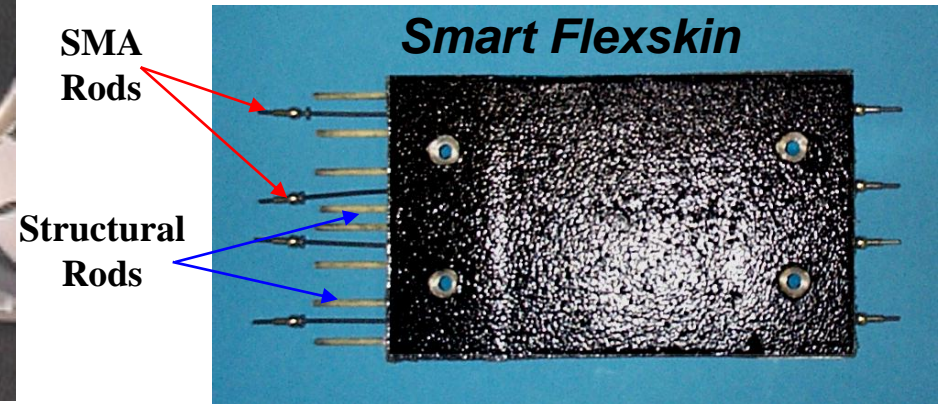
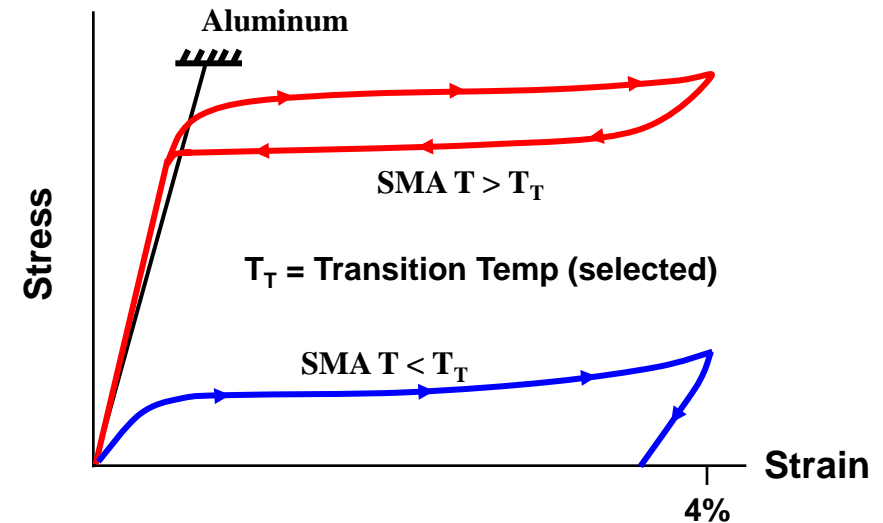


TBC / GDEB / PSU / LM / GT / NASA / NSWC / GTE-BBN

Leading Edge Flap Integrated Actuation by Shape Memory Alloy (SMA)

Engineering, Operations & Technology | Boeing Research & Technology

Multifunctional Structures



Three Key Technology Developments are Needed

Engineering, Operations & Technology | Boeing Research & Technology

Multifunctional Structures

- 1. Compact, highly weight efficient variable geometry primary load paths**
 - Highly anisotropic structural properties
 - Not just materials, novel structural architectures at all scales
- 2. Skins to provide fairings and gap closeouts to support the variable geometry**
- 3. Highly integrated, multi-degree of freedom actuators**
 - High energy/power density and high efficiency
 - Actuators must be controlled and controllable
 - Inherent feedback sensing is highly desirable

What's Stopping Adaptive Airframes?

- **Solutions based on kinematics of rigid structures are**
 - Usually too heavy (or perceived to be too heavy)
 - Introduce concerns with added complexity, reliability, maintainability
- **A key barrier is the benefits of adaptive airframes accrue at the platform performance level**
 - MDAO can simultaneously optimize aerodynamic and other platform performance along with structural design (for fixed airframe elements)
 - We are limited on our ability to do MDAO with adaptive airframe elements
 - We can create point designs for adaptive airframe solutions, but not within an MDAO environment
 - *Multifunctional Design adds another level of complexity that we must be able to handle*

And what have I forgotten? Oh yeah...

- **Size, Weight and Power (SWAP)**
- **Safety**
- **Life**
- **Thermal environments**
- **Load environments**
- **Graceful degradation**
- **All those good words ending in “...ility”**
 - **Reliability**
 - **Maintainability**
 - **Certiability**
- **Has it flown?**

Summary

- ***Adaptive Structures (applied to large structures) requires technology development in three areas***
 - ***Compact, weight efficient variable geometry load paths***
 - ***Large deformation/load bearing skins/fairings***
 - ***Integrated/Distributed Actuation***
- ***Design of Adaptive Airframes must be performed as part of system level trade studies and optimization***
 - ***The development of tools (particularly objective functions) to do this lags significantly behind the research SOA***
 - ***Multifunctional design is both the savior and the bane of Adaptive Structures***